

# Using Structured Decision Making to Explore Complex Environmental Issues

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## Abstract

Environmental issues are inherently complex, often requiring multiple interested parties to come together before agreeing on a solution. Structured decision making is a tool used by federal and state management agencies to find solutions that satisfy multiple stakeholder groups. We describe a role-playing activity, in which students are assigned various stakeholder roles and use structured decision making to try to come to consensus on solutions to an environmental problem. Here, we use the ecological and social issues associated with hydroelectric development in the Amazon basin as a case study. Before class, students read primary literature on the issues surrounding hydroelectric development and are assigned to stakeholder roles (climate scientist, fisheries scientist, indigenous leader, foreign investor, etc.). Students first work together within their given stakeholder role to create a diagram of their values (value tree) to help them design a solution and select measurable outcomes for the given environmental issue. Then in mixed groups, students represent their stakeholder group to discuss their different values and objectives. The students then return to their fellow stakeholder group and reflect on how exploring other views on an environmental issue influenced their own understanding of that issue. This lesson can provide students with a “capstone” activity to tie together biological concepts and ecological processes related to an environmental problem.

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**Supporting Materials:** S1. Structured Decision Making - Background Reading; S2. Structured Decision Making - White Paper Assignment; S3. Structured Decision Making - In-Class Worksheet; S4. Structured Decision Making - Handout; S5. Structured Decision Making - Activity Description; S6. Structured Decision Making - Pre-Class Questions; S7. Structured Decision Making - PowerPoint Presentation; S8. Structured Decision Making - Post-Activity Reflection

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## Learning Goal(s)

- Consider competing objectives and trade-offs around an environmental issue.
- Formulate scientific arguments based on evidence from primary scientific literature.
- Compromise to identify management strategies with measurable outcomes for an environmental issue.

## Learning Objective(s)

Students will be able to:

- Describe the process, challenges, and benefits of structured decision making for natural resource management decisions.
- Explain and reflect on the role of science and scientists in structured decision making and how those roles interact and compare to the roles of other stakeholders.
- Assess scientific evidence for a given management or policy action to resolve an environmental issue.

## INTRODUCTION

Complex environmental problems do not have simple solutions. Increasingly, ecologists recognize that stakeholders should be involved in the scientific process; this allows scientific information to be useful for decision making for socioecological issues (1). One tool that addresses decision making with multiple stakeholders and competing criteria is structured decision making (2). Structured decision making brings multiple stakeholders to the table and facilitates and focuses conversations about solutions among those diverse groups. Structured decision making explicitly considers values and viewpoints from academically, socially, and culturally diverse groups (2) and is used extensively by natural resource managers in state and federal agencies. For example,

structured decision making has been used successfully to guide the restoration of barrier islands in the Gulf of Mexico (3).

In an iterative process, stakeholders work together to first identify an environmental problem (e.g. managing a reservoir used for drinking water on a local river). They then define their respective objectives around that issue (e.g. ecological health of the reservoir, aesthetics of the reservoir, drinking water quantity and quality). Next, the stakeholders (e.g. local homeowners, county water board, aquatic scientists) discuss alternative options to those objectives, if they exist, and then the consequences of those objectives (e.g. clean drinking water may require a fence around the reservoir to exclude dogs). After that, they identify tradeoffs and learn to negotiate their desired objectives (e.g. a fence around the reservoir may not be aesthetically pleasing,

but could be constructed using natural materials while still protecting the drinking water supply). Finally, the stakeholders decide on the actions they will take and how they will evaluate if the environmental problem has been addressed (e.g. build the fence, then monitor drinking water quality and conduct surveys of residents' opinions of whether the fence is visually intrusive). At any point in this process, stakeholders may decide to return to an earlier decision making point. In this drinking water reservoir example, after discussing trade-offs with building a fence, local homeowners may re-visit their objectives and values and decide that the aesthetics of the reservoir are no longer as important to them as having clean drinking water.

As a class activity, structured decision making requires students to explicitly consider tradeoffs among different environmental management strategies and leverage the values of different stakeholders. Generally, role-playing improves general class performance by increasing participation, encouraging students to consider issues from multiple perspectives, and helping students develop their communication skills (4-6). Specifically, structured decision making involves active learning and may improve student's ability to formulate arguments (7,8). Furthermore, grappling with socioecological issues encourages students to engage with moral and ethical values (9). Moreover, because structured decision making is inherently interdisciplinary, using it repeatedly in the classroom for complex issues motivates students from diverse backgrounds to leverage their experiences and knowledge, giving them ownership over the activity (10). This lesson asks students to use scientific evidence and environmental ethics to support their arguments for a given strategy as they inhabit the roles of different stakeholders.

Semester-long courses in structured decision making exist and result in enhanced student scientific understanding (8,11). However, many pre-existing ecology or environmental science courses may also benefit from including one or several class sessions in which students can engage in the process, without necessitating a complete course overhaul. Here we describe a structured decision making lesson that we developed. We use the case study of hydroelectric development in the Amazon as an example topic that can be used to represent a complex issue with multiple stakeholder groups. Hydroelectric dams are one of the largest threats to Amazon biodiversity and ecosystem function (12-14) and represent a critical socioecological issue that puts economic development and biodiversity conservation in direct conflict (15). This lesson can be taught over a single class period as an opportunity for students to experience the structured decision making process. Alternatively, this lesson could be extended for multiple class periods to allow further opportunities to iterate the decision making process.

### *Intended Audience*

We developed this lesson for students in introductory or upper-level ecology courses. However, this activity is well suited for students of mixed majors, because it is interdisciplinary in nature. Moreover, this lesson can be a synthetic or capstone activity for a semester-long class in ecology or environmental science. We originally taught this lesson in a stream ecology course for life science majors at a large research university. We also modified and used this lesson in an introductory environmental science course for

non-traditional students working towards their associate's degrees as part of a prison education program at a maximum-security prison. In both cases, this lesson was taught as one of the final class sessions for the semester as a capstone activity.

### *Required Learning Time*

We taught this lesson in class periods ranging from 50 minutes to two hours in duration, with assigned pre-class reading and questions. When we taught this lesson in an introductory class, we scaffolded reading of the primary scientific article by discussing the main figures and findings of the article at the end of the class prior to the structured decision making activity. While we were limited to teaching this over one class period in some circumstances, we strongly recommend teaching this over multiple class periods if possible, to give students more time to reflect on and engage with the structured decision making process.

### *Pre-requisite Student Knowledge*

Students should understand the ecological underpinnings of the environmental topics being addressed. In the case of Amazon hydroelectric development, we taught students about ecological stream flows, how to read a hydrograph, the ecology of freshwater fisheries, the life histories of freshwater fish, and dynamics of sediment transport in streams and rivers. Instruction about these topics was already part of the original course in stream ecology, and we included them in two class sessions (one about freshwater resources and another about fisheries science) in the introductory environmental science course. Additionally, in both of these courses, students were already familiar with reading and discussing the primary scientific literature, which prepared them to read the assigned articles. Finally, we had already spent several class periods introducing the ecology of the Amazon ecosystem prior to the structure decision making activity.

To adapt this lesson for another course and a different case study, we advise that instructors choose an environmental topic already being covered in the course to make incorporating this lesson easier. Depending on the course level, you may need to spend a prior class period instructing students on how to read and comprehend a scientific paper, including providing written resources on strategies for reading primary literature (16). As an example, for an introductory ecology course, we created a cooperative learning activity ("jigsaw") to teach students how to read a scientific paper. We separated students into four groups and gave each group a part of a published scientific paper (Introduction, Methods, Results, Discussion). Each group had to read their section, discuss and summarize what was described in it, and report back to the entire class. We then discussed what types of information were shared in each section of a scientific paper and identified and explained passages that groups found confusing. Doing a similar activity prior to this lesson could scaffold students' ability to read the scientific literature, if similar scaffolding is not already part of the course.

### *Instructor Resources*

The main structured decision making tool that this activity uses is a value tree. Value trees are visual schematics that connect values or objectives (e.g. clean drinking water) to actual measurable outcomes of a decision (e.g. levels of *E. coli* in the drinking water supply after a fence is built around

the reservoir to keep dogs and people out).

Teachers should be familiar with the social and ecological implications of the environmental issue being discussed. Specifically, the instructor should understand the different stakeholder views and the scientific findings surrounding an ecological issue. In this Amazon hydroelectric development example, we are familiar with the ecological and economic issues because we both have worked in the Amazon basin. However, you do not need this level of immersion to be able to effectively teach this lesson! We provide additional resources for this example (Supporting File S1. Structured decision making - Background information). Another option is to select an environmental problem that you are particularly knowledgeable about or that is relevant to your students, including local issues with which you and your students may already be familiar. Importantly, the topic you select should be one that is controversial so that stakeholders are not already in agreement. A few examples of currently relevant environmental issues might include: 1. Using salt on the roads in the winter (beneficial for human safety, harmful for aquatic ecosystems); 2. Hunting top predators (beneficial for ranchers and hunters, harmful for food web structure and ecotourism); 3. Allowing pesticide use on agricultural crops (beneficial for food production, harmful for pollinators).

## SCIENTIFIC TEACHING THEMES

### Active learning

Active learning strategies used in this lesson include role-playing, a modified cooperative learning (“jigsaw”) technique, group discussion, and collaborative work in small groups.

### Assessment

Both times we taught this lesson, we used formative rather than summative assessment techniques because of pre-existing restraints on course requirements, assessment, and design. However, we would recommend using a mixture of formative and summative assessments to evaluate the learning objectives. Specifically, we would assign a white paper before the in-class session to evaluate students’ ability to synthesize the relevant scientific information surrounding the topic and a reflection prompt to evaluate how the in-class activity changed the student’s perspective on the environmental issue after the in-class session. We give an example of a prompt and a rubric for this assignment in which students write a white paper offering a scientific perspective and solution to the environmental issue prior to the in-class activity (Supporting Files S2. Structured decision making - White paper assignment & S8. Structured decision making - Reflection). The students then can modify their white paper after the in-class activity.

For assessing learning objective 1 (describing the structured decision making process), the group two-minute report-outs are a formative assessment evaluating how students describe their understanding of the structured decision making process.

For learning objective 2 (reflecting on stakeholder roles), the reflection statement and the group report-outs are formative assessments. Students self-evaluate their learning by completing the reflection exercise and by doing the brief report-out to the entire class.

Finally, for learning objective 3 (assessing scientific evidence), the white paper and in-class worksheets are the summative and formative assessments. Instructors collect and give complete/incomplete marks and feedback for the in-class worksheets.

### Inclusive teaching

Participants in structured decision making scenarios explicitly hold different viewpoints about an environmental topic. Therefore, this activity encourages students both to consider how others’ objectives and values might differ in regards to an environmental issue and how considering others’ viewpoints might influence their own views. Depending on how the instructor interacts with students during this lesson, this lesson can empower students to be stakeholders and citizens who can contribute to decision making about environmental problems (10). Additionally, structured decision making as a tool aims to make policy-making more transparent and integrates multiple academic disciplines with stakeholder interests.

In the Amazon hydroelectric development example provided in this lesson, students are encouraged to think about an environmental issue that affects a part of the world that may be socially and culturally distinct from their own experience. Likewise, you could select other environmental topics that are located in different cultures from those with which your students may be familiar.

This lesson is designed to ensure participation of all students in several ways. First, the instructor and any co-instructors or teaching assistants circulate among the groups to ensure that discussion time is equally shared. Second, the instructor can give timing prompts to give each member of the group an equal time to share their opinions. In addition, we recommend that the instructor assign a student in each group to be a discussion moderator to ensure equal participation of all students in the discussion. Finally, the mixed assessment method, using both formative and summative assessments, allows students to engage with the material in a variety of ways.

## LESSON PLAN

### *Preparation for Class*

#### Prepare worksheets and assign stakeholder roles

1. Either upload or photocopy the in-class worksheets used during the structured decision making activity (Supporting File S3. Structured decision making - In-class worksheet). When we taught the workshop, we used paper copies of the worksheets for students to fill out during the in-class session. However, if you prefer that students use laptops or if students need to use laptops for accessibility reasons, these worksheets could easily be filled out electronically.
2. Assign students their stakeholder roles prior to the in-class session (suggestions for roles can be found in Supporting File S5. Structured decision making - Activity description). You can do this either in the previous class or by posting assigned roles online. When we taught this lesson, we assigned stakeholder roles randomly, but depending on dynamics in their classrooms, instructors may choose to assign roles to

ensure equal participation of all students or let students self-sort into roles that match their values.

### Pre-class readings

1. Prior to class, students should read the handout describing the structured decision making process (Supporting File S4. Structured decision making - Structured decision making handout) and the class activity (Supporting File S5. Structured decision making - Activity description), along with assigned readings. For the Amazon dam example, students read a popular news article about the conflict between indigenous tribes and business interests around hydroelectric development in the Brazilian Amazon (17) with two primary science articles (12,13).
2. While reading, students were instructed to reflect on the perspectives and evidence shared in the articles relevant for their stakeholder role, using the pre-class worksheet (Supporting File S6. Structured decision making - Pre-class assignment). If desired, you could also instruct students to find and read their own sources to supplement the assigned material.

### Pre-class writing assignment

1. You can assign students a pre-class worksheet to structure their consideration of stakeholder values and objectives as they read the assigned materials (Supporting File S6. Structured decision making - Pre-class assignment). An option is to have students fill in their answers to a group Google document or similar online forum for each role, to start discussion before class.
2. For upper-level courses, or if doing this activity over multiple class periods, you can also assign a longer written assignment. We provide an example of a white paper assignment (Supporting File S2. Structured decision making - White paper assignment) that you could assign prior to the group activity. Students bring the first draft of their white paper with them to class.

### Pre-class mini-lecture during previous class (optional)

1. Depending on how familiar students are with the environmental issue you choose, you may decide to give a mini-lecture on the topic during class prior to the in-class structured decision making session. For example, when we used the Amazon dams case study in our introductory environmental science course, we gave a mini-lecture about the ecology of the Amazon River. In contrast, for our upper-level stream ecology course, we had been talking extensively about the Amazon River ecosystem throughout the course and did not feel that we needed to spend more class time talking further about that topic.

### *Class Session*

#### Mini-lecture on structured decision making

1. Before beginning the activity, give a short lecture on the structured decision making process.
2. Specifically, go through the planned schedule for the class session and how you expect students to fill out the worksheet in their home and mixed groups (Supporting File S7. Structured decision making - Powerpoint slides).

#### Home group discussion

1. For this first part of the activity, students should sit with students assigned to the same role to address the questions given in the class handout (Supporting File S3: Structured Decision Making - In class worksheet) and to construct a group value tree outlining their objectives and criteria.

#### Mixed group discussion

1. After home groups finish constructing their value trees and answer the decision questions, you should form mixed groups, with an expert representing each role in every group.
2. These mixed groups should spend the first part of their discussion sharing their value trees and answers to the questions in the class handout. Give timing prompts (e.g. "The member from the fisheries home group has 1 minute to share their value tree") to ensure that discussion time is equally shared.
3. During the second part of their discussion, the mixed groups should work to create a combined value tree and try to come to a consensus on their decisions to the discussion questions.
4. During these discussions, circulate among the groups to ensure all group members are equally participating.

#### Home group discussion

1. Finally, students return back to their home groups to discuss how meeting with other stakeholders influenced their values and objectives.
2. During this discussion, students should answer the discussion questions again with their fellow stakeholders and select a representative for the report out.

#### Individual reflection (optional)

1. If time allows, or if having individual time to reflect would benefit your group discussion, give students 5-10 minutes to think about reflection questions on their own (Supporting File S8. Structured decision making - Reflection). Students will finish responding to the reflection questions outside of class.

#### Group report out

1. To wrap up the class, have each group give a brief report-out (~ 2 minutes) on the decisions that they made in response to the questions in the class handout and how talking to different stakeholders changed their decision making process.
2. After the group report out, spend the remainder of class (~5 minutes) on a whole-class discussion reflecting on the decision making process. How difficult was it to come to a consensus? Why were you or why were you not actually able to come to a consensus? What surprised you about the decision making process? How did hearing other views change your group's perspective?

#### After class

1. Students will revise their white paper and complete the reflection questions as a summative assignment (Supporting Files S2. Structured decision making - White paper assignment & S8. Structured decision making - Reflection).



## TEACHING DISCUSSION

### *Lesson's Effectiveness*

Overall, we found that this lesson increased student understanding of the complexity of science and values surrounding an environmental issue and the structured decision making process. During the reflection period at the end of the lesson, students mentioned how difficult it was to come to a consensus on an environmental issue and that they had an increased appreciation for the values of different stakeholders. Both times that we taught this lesson, we observed students talking through their positions with their groups while pointing to and referring to the assigned primary research articles. Students use this time to also teach each other about parts of the primary research articles they struggled with. We also observed that this lesson provided students an opportunity to engage with a scientific topic from multiple perspectives. This activity illustrates how different stakeholders can come together in a positive way. Both times we taught this lesson, students with different backgrounds (e.g. political science majors), who had previously not been as active in class activities, played a much more active role during this lesson.

### *Student Reactions and Suggestions for Improvement*

Overall, students responded positively to the opportunity to role-play and work collaboratively. However, we have observed several ways that this lesson could be improved. First, one suggestion from a student was to assign a mediator in the mixed groups to ensure that each stakeholder representative has an equal opportunity to talk. Another way to resolve this issue would be for the instructor to be more hands-on with giving time warnings during the mixed group discussion (e.g. "Two minutes for the first stakeholder group, two for the second, etc."). Second, several students voiced that they wished they had more time to spend on this lesson. One option to address this feedback would be to expand this lesson across multiple class periods, or even as a semester-long activity. Finally, students were strong advocates for environmental justice and equitable access to opportunity. For example, some of the students representing the non-indigenous politician role advocated strongly for hydroelectric development because it would bring electricity to their community.

Finally, this lesson could be adapted to a number of different courses or student populations by modifying the topic and the level of the required readings. During the two times we taught this lesson, we required students to read one popular news article and two primary scientific articles. However, in adapting this to different courses, you could change the number of primary sources.

Structured decision making is a real-world tool that can also help students engage with environmental issues in the classroom. Here we have presented a lesson designed to engage students in the process of structured decision making. This lesson gives students an opportunity to explore an issue from multiple points of view by role-playing and interacting in group discussions, as well as reflecting individually.

## SUPPORTING MATERIALS

- S1. Structured Decision Making - Background Reading. List of resources for background information on issue of hydroelectric development in the Amazon.
- S2. Structured Decision Making - White Paper Assignment. Includes description and rubric (optional).
- S3. Structured Decision Making - In-Class Worksheet. Handout for students to fill out as they participate in the structured decision making workshop.
- S4. Structured Decision Making - Handout. Briefly describes what structured decision making is and how it is used to address environmental issues.
- S5. Structured Decision Making - Activity Description. Details about the structured decision making activity that you can hand out to students, including what is expected of them prior to and during class.
- S6. Structured Decision Making - Pre-Class Questions (optional).
- S7. Structured Decision Making - PowerPoint Presentation. Includes timer for different segments of structured decision making activity, including an overview of the activity for the beginning of the class.
- S8. Structured Decision Making - Post-Activity Reflection. Self reflection questions for after the activity (optional).

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**Table 1. Structured Decision Making - Teaching Timeline**

Activity	Description	Time	Notes
<b>Preparation for Class</b>			
Prepare worksheets & assign stakeholder roles	Make one copy of Structured Decision Making handout for each student for in-class session.  Either post online or provide in previous class the roles that each student will play in the structured decision making activity.	~ 5 minutes	Structured Decision Making handout is provided in Supporting File S3. Structured Decision Making – In-class worksheet.  If you prefer to have students working on their laptops during the in-class session, you can skip this step and simply provide the handout electronically.
Pre-class readings	At least one scientific article and one popular science article about the environmental issue, including its ecological and sociological implications.  Students should read the articles prior to coming to class.	~ 1-2 hours of reading	A handout explaining the structured decision making process is provided in Supporting File S4. Structured decision making – Structured decision making handout. Examples of readings used in Amazon Dam Example are provided in Supporting File S1. Structured decision making – background information.  For upper-level courses, you may want to assign more primary literature readings. For introductory courses, you may want to have more popular science readings.
Pre-class worksheet or white paper assignment	Worksheet giving assigned role to play in discussion with accompanying questions to consider and answer while reading.  White paper assignment requiring more research and synthesis on the student's part.	~ 1 hour	Doing the pre-class worksheet (Supporting File S6. Structured decision making – pre-class assignment) can help guide student thinking about their roles as they do the required reading. Additionally, it makes the class session, especially the first home group discussion, more efficient.  For upper-level courses or if doing this activity for multiple class periods, you may want to assign students a longer written assignment with a draft due before the class session. We give an example of an assignment description and rubric in Supporting File S2. Structured decision making - White paper assignment.
Pre-class mini-lecture during previous class (optional)	Give any needed background information for students to understand the readings prior to the in-class session.	~ 10-15 minutes	Depending on class level, this might be a good time to talk through figures and general findings from the primary literature articles to help students interpret the figures as they do the pre-class reading on their own.
<b>Class Session (options given for 50-minute or 2-hour class period)</b>			
Mini-lecture on Structured Decision Making	Brief lecture about structured decision making process, decisions being made during workshop, and overview of class schedule.	~ 10 minutes	Lecture slides with notes are in File S7. Structured decision making – Powerpoint slides.
Home Group discussion	Students work with others in their expert group to construct a consensus value tree and come up with their decisions about the issue based on their expressed values.	~ 10-20 minutes,	Instructor and any other teaching support can circulate among groups checking in on their progress.  Remind groups that everyone should be drawing the group value tree on their own worksheet.  Worksheets are in Supporting File S3. Structured Decision Making – In-class worksheet
Mixed Group Discussion	Combine one to two experts from each group together into a mixed group of stakeholders.  Work together to construct combined value tree and make decisions based on those values.	~ 10-20 minutes,	Be sure that each expert gets a chance to speak in the mixed group before mixed groups break into general discussion.  Again, remind groups that everyone should be drawing the combined value tree on their own worksheet.
Home Group discussion	Return to original expert group to discuss how decisions reached in mixed group.	~ 10-20 minutes,	This is an opportunity for expert groups to reflect on how meeting with other stakeholders might have changed their mind about their own values and objectives.

Activity	Description	Time	Notes
Individual Reflection (optional)	Gives individuals a chance to reflect on the activity before being asked to reflect with the entire class.	~ 10 minutes	Reflection sheet and prompts are available in Supporting File S8. Structured decision making – Reflection. If class time is short, this can be given as a post-class assignment, along with the white paper revisions (Supporting File S2. Structured decision making - White paper assignment).
Group Report-out	Have each home group give a 2-minute report-out.	~ 15 minutes	Home groups report on decisions reached and how their decisions changed after talking to stakeholders from other groups.
<b>After Class</b>			
White Paper Revision and Reflection	Each student revises their white paper based on how their position changed after going through decision making process and writes a reflection based on prompts.	~ 1-2 hours	White paper assignment and reflection assignment are available in Supporting Files S2 and S8 (S2. Structured decision making – White paper assignment & S8. Structured decision making – Reflection), respectively.